**Staff Summary**
**Method 2B Application**
**Brazilian Sugarcane By-Product Molasses-to-Ethanol**
**Raizen Energia S.A. – Costa Pinto Mill (COPI)**

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## Pathway Summary

Raizen Energia S.A. (Raizen) produces ethanol derived from sugarcane by-product molasses at their Costa Pinto (COPI) integrated sugar and ethanol production facility in the State of Sao Paulo, Brazil. Sugarcane is harvested on company-owned and partnership farms, and then transported to the COPI sugar mill and ethanol distillery located in the City of Piracicaba. After the sugarcane has been crushed, the cane juice is filtered, treated with calcium hydroxide, decanted, and then sent to sugar production. A by-product of the sugar production process is molasses which is the only feedstock sent to the ethanol distillery for fermentation and distillation, resulting in the production of anhydrous ethanol. The by-product molasses is however, not exhausted of its sucrose content and may have a higher value than molasses commonly sold as a livestock supplement.

The life cycle of the Raizen COPI pathway begins with sugarcane cultivation and transport, followed by sugar and ethanol production. The agricultural and ethanol production phases of this pathway are identical to those described in the ARB's Brazilian sugarcane ethanol pathway.[1] The majority of the sugarcane harvested in Sao Paulo State employs mechanical harvesters. The practice of harvesting manually, following pre-harvest burning, has largely been phased out at the Raizen sugarcane farms.

The Raizen COPI facility also generates and utilizes process heat and electricity from bagasse combustion for all its industrial operations. Surplus electricity produced is exported to the local electrical grid. The major difference between the proposed Raizen COPI pathway and the Brazilian sugarcane-based ethanol pathway is the type of feedstock. Raizen COPI utilizes molasses, the by-product from the sugar production process, whereas the Brazilian sugarcane ethanol pathway was based upon the use of pure sugarcane juice for ethanol production. Ethanol produced from fermentation of the molasses is transported by truck to the eastern port of Santos**,** and loaded onto ocean-going tankers for shipment to California. Ethanol transport and distribution modes in California are assumed to be identical to those used in the Brazilian sugarcane ethanol pathway.

[1] California Air Resources Board, 2009. Detailed California-Modified GREET Pathways for Brazilian Sugarcane Ethanol: Average Brazilian Ethanol, With Mechanized Harvesting and Electricity Co-product Credit, With Electricity Co-product Credit, version 2.3, September 23, 2009. http://www.arb.ca.gov/fuels/lcfs/092309lcfs_cane_etoh.pdf

## Facility Location and Coordinates

The Raizen Energia Costa Pinto sugar mill and ethanol production facility is located in the city of Piracicaba within the State of Sao Paulo, Brazil. The geographic coordinates of the centroid of the ethanol distillery, shown in the satellite view below, are 22°38'03" S (latitude), and 47°41'17" W (longitude).

**Satellite View of Raizen Energia Costa Pinto -**
**Sugar and Ethanol Production Facility**
**Piracicaba, Sao Paulo, Brazil**


## Carbon Intensity of the Raizen COPI Pathway

ARB staff has assessed the inputs used by Raizen Energia to determine its well-to-wheels (WTW) pathway carbon intensity. As sugar and molasses are products of the same agricultural, feedstock transport, and sugar production processes, the GHG emissions from these activities must be allocated between the two products. The

allocation method chosen by Raizen is the mass-based allocation methodology in which the total upstream and sugar production emissions are allocated on the basis of the ratio of the total reduced sugars (TRS) in the molasses entering the ethanol distillery to the total reduced sugars that enter the sugar production process for each ton of sugarcane that enters the factory gate.

Based on the mass ratio of the TRS in by-product molasses per ton of sugarcane to the TRS in the post-crush sugarcane juice stream per ton of sugarcane, Raizen COPI has determined that 14.75 grams of carbon dioxide-equivalent emissions per mega joule ($gCO_2e$/MJ fuel) of upstream and sugar production emissions should be allocated to the production of the by-product molasses. When these upstream and sugar production emissions are combined with ethanol production, addition of denaturant, transport, and distribution emissions, the total well-to-tank (WTT) life cycle GHG emissions for the Raizen COPI pathway are estimated to be 22.29 $gCO_2e$/MJ fuel. This WTT estimate includes the credit for mechanized harvesting (which offsets the straw burning emissions) but not the credit for exports of surplus cogenerated electricity.

The Raizen COPI mill exports surplus cogenerated electricity to the public grid. Due to the use of by-product molasses as a feedstock for ethanol production, the applicable electricity cogeneration export credit must be calculated differently however. The reason is that, when all of the sugarcane juice is sent to sugar production, the sugarcane bagasse that is generated after the cane crush is assumed to belong to the sugar mill. Since only the by-product of the sugar production process is fermented into ethanol, the credit is therefore assumed to be proportional to the fraction of fermentables (TRS) in by-product molasses to the total amount of fermentables[2] (TRS) in the pure sugarcane juice, measured after the cane crush. In other words, the mass allocation methodology used to allocate upstream emissions is also used to determine the quantity of surplus cogenerated electricity exports that should be credited to the by-product molasses pathway. The resulting electricity cogeneration and surplus export credit, based on a displacement of Brazilian marginal electricity, is estimated to be 21.86 $gCO_2e$/MJ of fuel produced. When applied to the WTT carbon intensity (CI) of ethanol, this credit results in a net WTT CI of 0.43 $gCO_2e$/MJ. When life cycle emissions due to land use change (LUC) of 46 $gCO_2e$/MJ are added to the WTT CI estimate, the final WTW CI for the Raizen COPI pathway is estimated to be 46.43 $gCO_2e$/MJ of ethanol fuel produced. Despite the allocation of some upstream emissions to the sugar production process, this change results in a CI for the COPI pathway that is comparable to that of sugarcane juice-derived ethanol. A summary of the disaggregated CI estimate for the Raizen COPI pathway is presented in Table 1 below.

[2] This ratio was found to be 0.34. It is the same mass allocation factor for estimating the contribution to the Raizen COPI pathway from upstream emissions.

## Table 1: Summary of Disaggregated WTW GHG Emissions for the Raizen COPI By-Product Molasses-to-Ethanol Pathway

| Disaggregated Item | Value Reference | Total Sugar Production GHG Emissions: (g $CO_2$e/MJ) | GHG Emissions Allocated to Molasses Ethanol : (g $CO_2$e/MJ) |
|---|---|---|---|
| ***Well-to-Tank (WTT) Allocated GHG Emissions:*** | | ***Raizen COPI Mass Allocation Factor: 0.34*** | |
| Sugarcane Farming | See Worksheet* "Cane Farming 1113" | 4.97 | 1.71 |
| Agricultural Chemicals Use | See Worksheet* "Cane Farming 1113" | 26.23 | 9.00 |
| Straw Burning Emissions | See Worksheet* "Straw Burning 1013" | 22.74 | 0.71 |
| - Less Credit for Mechanized Harvesting | Raizen COPI Claimed Mechanization Level: 90.9 % | (20.67) | - |
| Sugarcane Transport | See Worksheet* "T&D" | 3.71 | 1.27 |
| Sugar Production | See Worksheet* "Allocation" | 5.99 | 2.06 |
| ***Total Upstream GHG Emissions:*** | | 42.97 | **14.75** |
| Ethanol Production | See Worksheet "EtOH Prod" | - | 2.21 |
| Ethanol Transport & Distribution | See Worksheet "T&D" | - | 4.53 |
| Addition of Denaturant | Indonesian Molasses Pathway | - | 0.80 |
| ***Well-to-Tank (WTT) GHG Emissions Estimate Before Electricity Export Credit:*** | | - | ***22.29*** |
| Electricity Cogeneration and Surplus Export Credit | See Worksheet "Cogen Exp Cr" | - | (21.86) |
| ***Total Well-to-Tank (WTT) CI Estimate:*** | | - | **0.43** |
| ***Tank-to-Wheels (TTW) GHG Emissions Estimate*** | | | |
| Carbon in Fuel | 1,000,000 Btu / mmBtu Anhydrous Ethanol Produced | N/A | N/A |
| Land Use Changes | See Worksheet "Prop ILUC" | | 46.00 |
| ***Final Well-to-Wheel (WTW) CI Estimate:*** | | | **46.43** |

* All Worksheets referred to are worksheets within the Spreadsheet entitled "Final Staff Disaggregation Analysis for Raizen-COPI.xlsx" (see posted "Supporting Information.")

A mass-based allocation factor was used to adjust the ILUC increment downward in the previous Indonesian and Central American sugarcane byproduct molasses-to-ethanol pathways. The full yield of ethanol from sugarcane juice per metric tonne of sugarcane was used in the denominator of this allocation factor to reflect the dynamics of the sugar and molasses markets in Indonesia and Central America. While sugar is a relatively high-valued export commodity in these regions, molasses was historically sold into local livestock feed markets (its value is too low to justify exports). The use of by-product molasses as an ethanol feedstock increases its value, but changes in the value of a by-product can only have a limited effect on the production of the primary product. Hence, the increase in the value of by-product molasses as an ethanol feedstock will have a limited effect on the amount of land brought into sugar cane cultivation. The demand for ethanol produced directly from sugar cane juice, on the other hand, directly drives the amount of land under sugar cane cultivation. When used as ethanol feedstocks, therefore, sugar cane juice and molasses will not have equal effects on the amount of land brought into sugar cane cultivation, and only a fraction of the ILUC could be apportioned to by-product molasses.

Staff however, re-evaluated the extent to which the Brazilian sugar, ethanol, and molasses markets are similar to the Indonesian and Central American markets. The result was a finding that the markets in which Raizen COPI operates bears little similarity to the corresponding Indonesian and Central American markets. The primary differences are (a) that molasses is produced exclusively as an ethanol feedstock for use within the integrated sugar and ethanol production complex (no outside market for molasses exists, and (b) that the feedstock molasses used in the Raizen COPI mill is not “exhausted” molasses like that used in Indonesia and Central America. These differences indicate the molasses used in the Raizen COPI mill can have a significant effect on the demand for cane juice and, by extension, the amount of land under sugar cane cultivation. There is no basis, therefore, for reducing the contribution of ILUC to the carbon intensity (CI) of the Raizen COPI molasses pathway. Therefore, staff will require that the Raizen COPI pathway (and others like it in the future) include the full sugar cane ethanol land use change estimate of 46 $gCO_2e/MJ$. The proposed Lookup Table entry for the Raizen COPI pathway is presented in Table 2 below:

**Table 2: Proposed Lookup Table Entry for Fuel/Feedstock**

| Fuel | Pathway Identifier | Pathway Description | Carbon Intensity Values ($gCO_2e/MJ$) | | |
|---|---|---|---|---|---|
| | | | Direct Emissions | Land Use or Other Indirect Effects | Total |
| Ethanol | ETHM004 | 2B Application (Specific Conditions Apply): Brazilian sugarcane by-product molasses-based ethanol with average production processes, and credits for electricity co-product and mechanized harvesting. | 0.43 | 46.00 | 46.43 |

## Applicable Operating Conditions

Operations at the Raizen COPI plant will be subject to the following conditions designed to ensure that the CI of the by-product molasses-based ethanol sold under the pathway described in this Staff Summary will remain at or below the value appearing in Table 2. The conditions must be met for every gallon of ethanol sold by Raizen COPI in California. Exceptions are allowable only in the case of brief periods of planned maintenance or unpredictable, unavoidable, and uncontrollable force majeure events.

1. In order for Raizen COPI to sell ethanol in California using the fuel pathway described in this document, only the by-product molasses from Raizen COPI's sugar production process may be used as feedstock for the ethanol plant. By-product molasses is the by-product of the sugar production process and has the approximate quality and ethanol yield of 85°Brix and 286 liters per short ton of molasses, respectively.

2. The mass allocation ratio as determined from the mass flow rate of total reduced sugars (fermentables) in by-product molasses per ton of sugarcane being sent to the ethanol distillery to the mass-flow rate of the total reduced sugars in the pure post-crush sugarcane juice stream per ton of sugarcane, shall not exceed 0.34.

3. The total volume of ethanol produced for export to California shall not exceed the volume calculated on the basis of the theoretical mass crush rate of 1,000 metric tonnes sugarcane per hour for sugar production, an ethanol yield of 6,023 gallons per hour, and the applicable operating conditions 1 and 2 above.

4. The CI for ethanol produced by the Raizen COPI pathway is based on the allocation factor Raizen applied to upstream emissions from sugarcane farming, agricultural chemical use, the estimated fraction of in-field straw burning, sugarcane transport, and sugar production. Raizen's allocation factor is identified in the worksheet "Allocation."[3] If any of the input assumptions or parameters used to determine the allocation factor are changed, the CI estimate may no longer be valid. ARB must be notified of such changes as they occur, and their impacts on the ethanol fuel CI must be re-assessed.

5. The CI for ethanol produced by the Raizen COPI pathway includes a credit for electricity cogeneration and surplus exports. If the bagasse is used for any purpose other than cogeneration of electricity, or if additional bagasse is brought into the facility for cogeneration from outside the Raizen COPI mill, or if the boilers are de-rated, then the CI for the ethanol produced may no longer be valid and must be reassessed.

[3] See spreadsheet entitled "Final Staff Disaggregation Analysis for Raizen-COPI.xlsx" posted in "Supporting Information."

## Staff Analysis and Recommendations

Staff has reviewed Raizen Energia's application for certification of a Brazilian sugarcane molasses-based ethanol pathway and finds the following:

- Staff has replicated with reasonable accuracy, using a mass-based allocation methodology, the CA-GREET GHG lifecycle emissions modeling spreadsheet, and other input process parameters furnished by Raizen COPI, the CI value being proposed for certification.

- Staff recognizes that the plant energy (process heat and electricity) consumption values reported for Raizen's process reflect cogeneration activities from bagasse combustion with surplus electricity export to the public grid. In addition, the pathway well-to-tank GHG emissions analysis reflects applicable credits for the use of mechanized harvesting practices at the sugarcane farms.

- Staff agrees that the mass-based method used to allocate GHG emissions to the upstream sugarcane farming, transport, and sugar production processes is valid and representative for the Raizen COPI pathway being proposed for adoption.

- Staff proposes an interim approach to estimate the impact of indirect land use change (ILUC) emissions for this pathway based upon the ILUC estimate for ethanol derived from pure Brazilian sugarcane juice pathway. A revised interim or final value for ethanol derived from pure sugarcane juice or by-product molasses in Brazil may be proposed in the near term.

On the basis of these findings, ARB staff recommends that Raizen's application for a Method 2B LCFS pathway be approved with a CI of 46.43 $gCO_2e/MJ$ of ethanol fuel produced at the Costa Pinto mill using byproduct molasses as the only feedstock.